APPENDIX D

ARIMA FORECASTS PROVIDE THE BEST WAY OF DETERMINING A PCI ADJUSTMENT FACTOR ON A GOING-FORWARD BASIS THAT IS CONSISTENT WITH MIMICKING COMPETITION.

In this section, GTE will briefly outline an ARIMA forecasting method which could be used to predict the PCI on a going forward basis -- the one-year ahead forecast based on the most up-to-date data set being used as the PCI adjustment factor.

Let

$$y_t \quad t=0,\cdots,T-1$$

be an observed series of PCI adjustments. These are not the ones predicted by the Commission and imposed as the PCI adjustment factor. Rather, these are the PCI adjustments actually observed as calculated using the LEC direct method based on industry data. These data are analyzed using ARIMA time series methods. That is, the data are investigated to see if there are trends or unit roots. If so, the data are differenced up to the degree of integration. It is unlikely that the PCI series will exhibit unit roots, so GTE will treat only the more standard stationary case. GTE postulates that:

$$y_t - m = \sum_{i=1}^{p} a_i\left(y_{t-i} - m\right) + \sum_{j=0}^{q} q_j e_{t-j}$$

where the ε are white noise errors, p and q are values determined in the identification phase by examining the direct, inverse, and partial autocorrelation functions, and the μ, α and θ are unknown parameters whose values are to be determined in the estimation phase. This assumption is based on the fact that most time series can be represented this way. Those that cannot are rare and easily fixed. All the estimation, identification and forecasting can be performed quickly on a personal computer using off-the-shelf statistical software such as SAS Institute's PROC ARIMA.

Once the μ, α and θ are estimated, the forecast is made using the *p* most recent values of the *y*'s and the *q* most recent values of the ε which are fit as part of the forecasting process. This is performed automatically by any good forecasting software, such as the SAS Institute's mentioned above.

For the PCI, the Commission has two choices. The first is to use the one-period ahead forecasts as discussed. The second would be to ignore any short term variation and to use the long-run equilibrium value of the PCI process. The long-run equilibrium value of this growth is simply μ.

Presumably, these calculations, as well as the forecasts, would be performed by qualified outside analysts. However, the LECs, as well as the Commission staff, can easily do the calculations themselves to aid in longer term decision making; *e.g.*, forecast for more than one year if need be. The first year forecast should be used as the PCI adjustment factor, and subsequent years as estimates for planning purposes.

GTE's analysis, which is based on the data exhibited in Appendix F of the *First Report and Order*, is contained in Appendix E. This analysis suggests that the PCI is an AR(1) process with long-run equilibrium growth of 1.9, and a coefficient of 0.48.

APPENDIX E

GTE's ANALYSIS OF THE DIRECT METHOD

Below is the code written in SAS 6.10 for Windows that was used in GTE's analysis.

```
data newdat;
set c.fccdat;               * data from Appendix F of the First Report and Order;
pci_gte=lecip-lectfp;       * calculate the pci adjustment factor using the icc method;
run;
proc print;
run;
proc arima;
identify var=pci_gte;       * determine what type of series pci_gte is;
                            * the next step is usually run after analyzing the;
                            * results of the identification procedure;
                            * here we use the fact that the series was;
                            * already identified.  And use the results;
estimate p=1 q=0;           * estimate the process after it has been identified;
forecast lead=1;            * forecast the next year after the end of the series;
run;
```

The following pages contain the output from the code. Annotations in italics were added by GTE for explanation. The graphs were reworked from printed output for readability. Some extraneous spacing and redundant tables were deleted.

OBS	YEAR	USIP	LECIP	LECTFP	USTFP	GDPPI	PCI_GTE
1	1949	-1	3.2	-1.1	0.3	0	4.3
2	1950	6.3	5.1	4.5	4.4	0	0.6
3	1951	7.9	8.8	4.8	2.4	0	4
4	1952	1.2	8.8	2.3	0.1	0	6.5
5	1953	3.7	2.4	0.9	0.2	0	1.5
6	1954	0.6	1.9	0.8	-0.8	0	1.1
7	1955	6.6	5.4	5.2	4.4	0	0.2
8	1956	0.7	1.7	1.4	-1.4	0	0.3
9	1957	3.7	-1.1	5.2	0.3	0	-6.3
10	1958	0.5	3.3	1.6	-0.6	0	1.7
11	1959	7	5.4	5.8	4.2	0	-0.4
12	1960	-0.6	4.2	3.9	-1.6	1.44	0.3
13	1961	3.6	3.9	2.2	2.9	1.06	1.7
14	1962	4.4	2.2	3	2.3	1.4	-0.8
15	1963	3.8	1	2.3	2.7	1.38	-1.3
16	1964	4.5	6	3.1	3.2	1.37	2.9
17	1965	5.7	0.5	2.9	3.1	1.68	-2.4
18	1966	4.6	1.1	4.3	1.8	2.98	-3.2
19	1967	2	1.9	3.3	-0.2	3.22	-1.4
20	1968	4.4	4.2	4.4	0.7	4.36	-0.2
21	1969	3.7	2.1	3.8	-0.8	4.78	-1.7
22	1970	3.3	3.8	0.6	-0.9	5.13	3.2
23	1971	6.8	4.2	1.1	2.2	5.15	3.1
24	1972	7.2	8	4	2.9	4.38	4
25	1973	6.3	0.6	4.3	0.9	5.43	-3.7
26	1974	4.2	5.9	3.7	-3.5	8.9	2.2
27	1975	9.4	14.2	2.8	0.1	9.46	11.4
28	1976	9.1	10.7	4.4	2.7	5.7	6.3
29	1977	8.6	6.1	3.6	2	6.51	2.5
30	1978	7.8	7.6	4.8	0.8	7.33	2.8
31	1979	8.2	7.2	4.2	-0.1	8.46	3
32	1980	6.6	14.6	5.1	-1.6	9	9.5
33	1981	9.9	11.6	0.5	0.9	9.22	11.1
34	1982	3.7	12.1	1	-3	6.3	11.1
35	1983	5.6	12.8	4.3	2	4.15	8.5
36	1984	7.4	1.8	-2.2	3.5	3.64	4
37	1985	4	0.1	1.1	0.5	3.51	-1
38	1986	3.8	1.3	2.8	1	2.86	-1.5
39	1987	3.1	1.7	1.8	0.2	3.09	-0.1
40	1988	4.4	-3.2	2.1	0.5	4	-5.3
41	1989	4.1	-3.7	2	-0.2	4.42	-5.7
42	1990	4.2	11.9	4.6	-0.3	4.6	7.3
43	1991	2.9	1.3	1.2	-1	3.96	0.1
44	1992	5.1	4.4	3.5	1.5	3.22	0.9

ARIMA Procedure

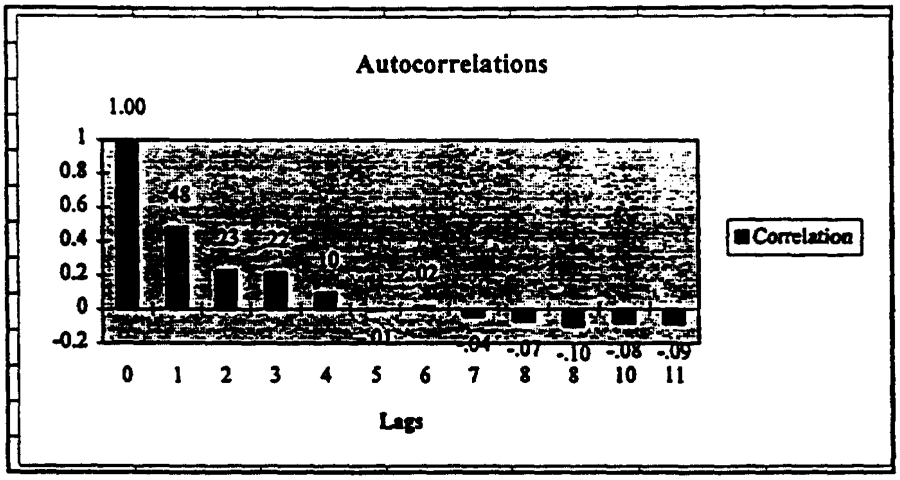
Name of variable = PCI_GTE.

Mean of working series = 1.843182

Standard deviation = 4.260143

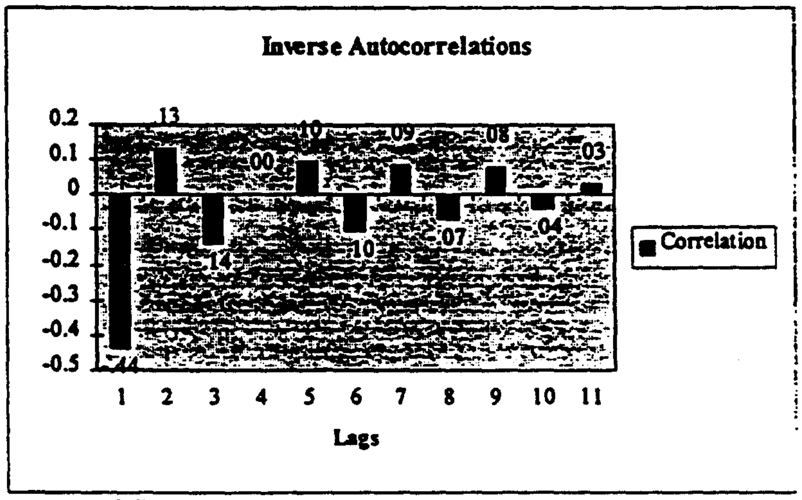
Number of observations = 44

Autocorrelations



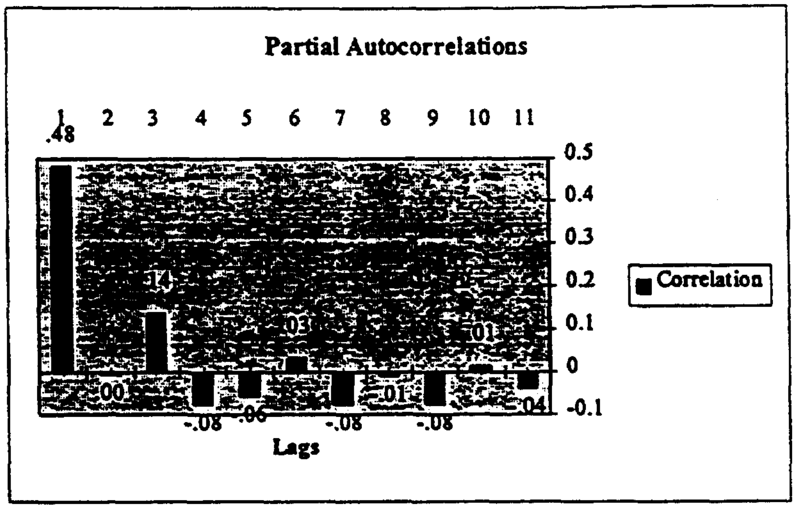
Autocorrelations show an exponentially damped pattern suggesting an AR process.

Inverse Autocorrelations



Inverse auto correlations show a spike at 1 lag indicating an AR(1).

Partial Autocorrelations



Partial Autocorrelations show the same pattern as Inverse Autocorrelations; this also suggests an AR(1).

ARIMA Procedure

Autocorrelation Check for White Noise

To Chi Autocorrelations

Lag Square DF Prob

6 16.13 6 0.013 0.480 0.227 0.216 0.097 -0.007 0.015

Autocorrelation test shows a strong time series component.

ARIMA Procedure

Estimate an AR(1) based on the identification phase above.

Conditional Least Squares Estimation

Parameter	Estimate	Std Error	T Ratio	Lag
MU	1.91819	1.07725	1.78	0
AR1,1	0.48092	0.13541	3.55	1

Estimates of the AR process MU is the long-run AR1,1 is the coefficient on the lag.

Constant Estimate = 0.99569355

This is the estimate of the constant or intercept, not the long-run value.

Variance Estimate = 14.6258152

Std Error Estimate = 3.82437121

AIC = 244.862388*

SBC = 248.430767*

Number of Residuals= 44

* Does not include log determinant.

Correlations of the Estimates

Parameter	MU	AR1,1
MU	1	0.012
AR1,1	0.012	1

Autocorrelation Check of Residuals

To Chi Autocorrelations

Lag Square DF Prob

			Autocorrelations						
	Chi-Sq	df	Prob	1	2	3	4	5	6
6	1.65	5	0.895	0.001	-0.068	0.136	0.028	-0.076	0.056
12	2.56	11	0.995	-0.033	-0.022	-0.064	-0.014	-0.041	0.086
18	10.93	17	0.860	-0.220	-0.166	0.016	0.023	-0.186	-0.093
24	14.65	23	0.907	0.010	0.086	-0.123	0.019	0.111	-0.073

Autocorrelations show elimination of strong time series components in residuals.

Analysis is done

Ready to forecast

Model for variable PCI_GTE

Estimated Mean = 1.91819461

Autoregressive Factors

Factor 1: 1 - 0.48092 B**(1)

ARIMA Procedure

Forecasts for variable PCI_GTE

Obs	Forecast	Std Error	Lower 95%	Upper 95%
45	1.4285	3.8244	-6.0671	8.9242

Forecast of the PCI adjustment for 1993 based on data is 1.4285.

APPENDIX F

GTE CALIFORNIA INCORPORATED TESTIMONY AND REPLY TESTIMONY OF DR. GREGORY M. DUNCAN

Case No.: I.95-05-047
Exhibit:
Witness: Gregory M. Duncan
Date:

GTE CALIFORNIA INCORPORATED

TESTIMONY OF DR. GREGORY M. DUNCAN

Q. Please state your name and your business address.

A. My name is Gregory M. Duncan. My business address is 40 Sylvan Road, Waltham, Massachusetts 02154.

Q. By whom are you employed and in what capacity?

A. I am employed by GTE Laboratories, Inc. ("GTE Labs") and work within its Department of Economics and Statistics. I am a Staff Scientist with responsibility for developing, proposing and conducting research, as well as supervising the research of the other economists and statisticians at GTE Labs.

Q. What is GTE Labs?

A. GTE Labs is the central research and development facility for GTE. Its mission is to provide technical leadership to GTE business units, including GTE California, by conducting research and development activities in areas which will enable the various GTE business units to understand and utilize new advancements in technology. This service involves providing the management of the GTE business units with appraisals of technical trends, systems analyses, and economic assessments to insure the incorporation of technical and economic awareness in the management planning and decision process.

GTE Labs maintains academic ties with many prestigious universities to ensure that GTE stays on the cutting edge of technology. Indeed, of GTE Labs' staff of

600, approximately 500 have Ph.Ds and many hold or have held teaching positions at Harvard, Massachusetts Institute of Technology (MIT) and Boston University. I myself have taught on the faculty of Boston University.

Q. Please describe your educational background and work experience.

A. I received a M.A. in Statistics in 1974 and a Ph.D in Economics in 1976 from the University of California, Berkeley. Beginning in 1975, I taught in the Economics Department and Statistics Program at Northwestern University in Evanston, Illinois, where I was an Assistant Professor of Economics and Statistics. My teaching responsibilities included Demand and Production Theory, Econometrics and Statistics, and graduate level Time Series and Discrete Choice Analysis courses. I also conducted research on demand and production, as well as in time series and discrete choice analysis, which appeared in refereed journals. I left Northwestern in 1979 to join the faculty at Washington State University, where I served as a Professor of Economics and of Statistics. My research continued in demand theory, production analysis, time series, discrete choice analysis and applications, as well as in other topics. During that period, I was one of the first Associate Editors of the academic journal Econometric Theory. Since that time, I have published many refereed papers in demand analysis, production analysis, and consumer and firm behavior.

I joined GTE Labs in 1987. I currently do a great deal of internal consulting within GTE Corporation, which has exposed me to all facets of the telecommunications industry, including specifically, forecasting and demand analysis. I have worked closely with the Demand and Forecasting group within GTE Telephone Operations over the last seven years on a variety of demand analysis issues ranging from developing a forecasting system using state-of-the-art time series procedures to assisting in developing robust regression procedures.

Q. Have you testified before this Commission in the past?

A. Yes. I testified for GTE California Incorporated (GTEC) in Case No. I.87-11-033, Phase III Implementation Rate Design (IRD).

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to recommend a productivity offset factor for use in the price cap mechanism in the event that the Commission chooses to retain the "x" factor as part of the price cap mechanism.

Q. Are you aware of studies which address computation of an appropriate productivity factor for the telecommunications industry?

A. Yes.

Q. At this time, do you recommend any particular study and in its findings regarding appropriate productivity factors?

A. Yes. My recommendation is to adopt the productivity factor established in the study entitled "Productivity of the Local Telephone Operating Companies" by Christensen, Schoech and Meitzen ("the Christensen study"). I endorse both the analysis and results of this study. The most recent update of this study concludes that the proper telecommunication productivity factor is 2.1 percent.

Q. On what basis do you endorse the Christensen study?

A. First, Dr. Christensen, along with Professors Dale Jorgensen (at Berkeley and Harvard), Daniel McFadden (at Berkeley and MIT), Lawrence Lau (at Stanford), and Irwin Diewert (at Chicago and University of British Columbia) and their students, invented most of the production, cost and productivity methods which are used today. Among these methods are the total factor productivity methods, but also, index number theory, that is, the correct way of measuring input and output price changes. These methods are properly applied in the Christensen study.

Second, Dr. Christensen is one of the most prolific and highly regarded researchers in the area of production and productivity measures. Indeed, he is one of the most cited and well respected authors in the economics literature. Dr. Christensen is a theoretical and applied econometrician of the first rank.

Q. Have you personally reviewed the Christensen study?

A. Yes.

Q. What are your opinions as to the relevance of this study to the present NRF Reform proceeding?

A. To the extent the Commission decides to maintain a productivity adjustment factor, they should use the proper one. Dr. Christensen's study produces an appropriate productivity factor.

The methodology of the Christensen study is the same that I would use if I were to do an independent study and analysis of the telecommunications industry. Based upon my knowledge and respect of the individuals performing the study and based upon my review of the study, I have the highest confidence in and agree with the results reported in the Christensen study.

Q. You previously stated that the Christensen study uses the correct methodology for measuring input and output changes. What is the correct way of measuring these changes?

A. The Christensen study uses GDPPI as the output price adjustment factor, and does not use a similar adjustment of the input prices. This is appropriate. Since the telecommunications industry competes on the competitive market for labor, materials and equipment, and since this equipment is produced in competitive markets, the relevant price index is the overall United States market input price index. Thus, there is no differential between local exchange carrier input prices and overall United States economy input prices that needs to be reflected. Tests performed by the Christensen study and parallel tests performed by National Economic Research Associates ("NERA") showed no evidence of a long run deviation in the series of input prices between the telecommunications industry and the United States economy.

Q. What is the issue with regard to comparing the inflation faced by telephone companies in their input prices, versus the inflation that occurs in the general economy?

A. This issue has been raised by some parties in other proceedings, and we anticipate that it may also be raised here. Typically, the claim is something like the following: (1) the prices of the inputs that local telephone companies buy face inflation at a lower rate than the general rate of inflation in the economy; so (2) using an economy-wide inflation index for the price cap gives local telephone companies too much of an inflation adjustment; so (3) regulators should increase the productivity offset to adjust for this claimed difference.

Q. What is the problem with this claim?

A. It is simply wrong, in at least two senses. First, as a matter of fact it is not true that what telephone companies buy is subject to less than average inflation. Second, even if it were true, the suggested remedy is wrong--because in such an unusual situation, the economy would adjust to reduce the gap (which is to say, the purported benefit in this example) so that local telephone companies would never get the opportunity of keeping this claimed differential as extra profits.

Q. What needs to be done to test whether the labor, goods and services that local telephone companies buy are facing inflation at an unusually low (or high) rate?

A. To test this, we need to look at what is called a price series, which is a set of data developed to show what the prices actually were for the purchase of certain types of goods and services over a period of time. For this analysis we need two price series--the one for the inputs local exchange carriers buy, and the one for the United States economy as a whole. We can then perform a battery of standard statistical tests to compare the two price series, and to see whether they are the same, or different.

Q. If the two price series are the same, would you expect to see identical values for each time period?

A. No, you would not. Random statistical fluctuations are to be expected, which will make the two sets of data somewhat different. However, if the two price series are the same, then over time you would expect those fluctuations to even out.

Q. What would happen if the telecommunications input prices grew at a rate faster than the economy as a whole?

A. This is an area where economists have a very good analysis to describe what might happen in the event that telecommunications input prices were deviating from the general economy as a whole, which, as I have already demonstrated, they are not. But just to complete the analysis, I will describe what would happen if for some reason this was the case.

Essentially, if input prices were to deviate in this fashion for one sector of the economy, the economy as a whole would adjust to make that deviation smaller and eventually cause it to disappear.

If telecommunications input prices grew at a rate faster than the economy as a whole capital and labor would migrate to telecommunications. This would depress prices in the telecommunications market and increase them in the United States market as a whole, thus closing the gap.

Similarly, if telecommunications prices grow more slowly than the United States economy as a whole, labor and capital migrates out of the industry. This would increase prices in telecommunications while depressing the prices in the economy as a whole, thus again decreasing any gap. A persistent gap is inconsistent with what we know about both labor and capital markets. The market tends to make similar jobs in the labor market have similar wages. The same is true in equipment markets: Electric motors used in telecommunications cost the same as those in shipping. The computer chips running a Class-5 telecommunication switch cost as much as the same chips monitoring the heating and cooling system in a manufacturing plant. A Pentium sold to GTE costs the same as a Pentium sold to General Motors.

Economists speak of such series that move together as being cointegrated and while they may differ in short run fluctuations, over time, they behave in a similar fashion.

Q. Have you run any tests of your own to confirm the results of the Christensen study?

A. Yes. I ran a very simple cointegration test between the local exchange carrier input price growth series used in the Christensen study and the LEC-United States price series used in the recent FCC price cap proceeding (CC Docket No. 94-1, Appx. F), as well as performing standard Autoregressive Integrated Moving-Average ("ARIMA") analyses on each of the series and the difference between the series.

Q. What can you conclude from your test?

A. Based upon my test, I conclude that the input series are cointegrated. There is no evidence to support the contention that the telecommunications input price series moves differently than the United States input series except for spurious random fluctuations which can be disregarded as I explain below. My calculations appear in Attachment A.

Additionally, rather than merely performing a simple means analysis or regression analysis of the types used by Christensen and NERA, I also performed a complete ARIMA analysis of the difference between the input price series as well as the input price series themselves. My findings support those of the Christensen study, as well as those of NERA. First, there is no evidence the series differ in mean. This means they behave the same way in the long run. Second, the local exchange carrier price input series is quite a bit more volatile than the United States input price series. Third, the only differences between the series are the result of totally random zero-meaned noise.

Q. What do such findings mean?

A. They mean that there is no long run deviation between the growth in the local exchange carrier input price index and the United States economy input price index. Thus, the Christensen study is correct in not adjusting for spurious deviations in an input price series.

Q. Does the productivity factor set forth in the Christensen study include a "stretch" element like that which exists in the Commission's current productivity factor?

A. No.

Q. Is the use of a "stretch" in a productivity factor appropriate in today's environment?

A. No, it is not. A "stretch" factor is merely an arbitrary extension of a productivity factor. In a competitive environment, a productivity factor is undesirable in itself and places an asymmetric burden on the LECs. To place an extra "stretch" on an already burdened LEC has the potential to severely (and perhaps irreparably) harm a LEC.

Q. Does this conclude your testimony at this time?

A. Yes.

ATTACHMENT A

ARIMA Procedure

Correlations of the Estimates

Parameter	MU	AR1,1	AR1,2
MU	1.000	-0.001	0.010
AR1,1	-0.001	1.000	-0.089
AR1,2	0.010	-0.089	1.000

ARIMA Procedure

Autocorrelation Check of Residuals

To Lag	Chi Square	DF	Prob	Autocorrelations					
6	7.67	4	0.105	-0.011	-0.001	-0.096	-0.098	-0.133	-0.381
12	8.91	10	0.541	0.109	0.061	0.085	0.047	0.018	0.036
18	12.61	16	0.701	-0.015	-0.057	0.075	-0.038	-0.204	-0.016
24	18.52	22	0.674	-0.061	0.130	-0.042	0.088	0.155	-0.052

ARIMA Procedure

Model for variable DIFF

Estimated Mean = 0.61139021

Autoregressive Factors
Factor 1: 1 - 0.10146 B**(1) + 0.14159 B**(2)